ERS-Foreign 322

HIGH-YIELDING VARIETIES OF WHEAT IN DEVELOPING COUNTRIES

U.S. DEPARTMENT OF AGRICULTURE • Economic Research Service

ABSTRACT

The production of high-yielding varieties of wheats in developing countries in recent years has been so successful as to be termed a Green Revolution. These wheats (semidwarfs), originating in Mexico, are short stemmed, photo insensitive, and highly responsive to inputs. Total semidwarf wheat area in India, Pakistan, Mexico, Turkey, Afghanistan, Tunisia, Iran and Morocco, expanded rapidly from 0.6 million hectares in 1966 to 10.6 million hectares in 1970. Production during the same period increased from 1.6 million tons to 22.7 million tons. In 1970, semidwarf wheat in these countries accounted for 25 percent of the total wheat area and 49 percent of the total wheat output. This agricultural advance is attributed to programs developed by individual governments with the assistance of international institutions and private agencies.

Key words: High-yielding wheat varieties, semidwarf wheat, wheat production, Green Revolution, developing countries.

FOREWORD

The worldwide importance of the Green Revolution--the introduction and use of high-yielding varieties (HYV) of semidwarf wheat--was recently attested by the awarding of the Nobel Prize to Dr. Norman E. Borlaug, the developer of the new wheat varieties. Because this revolution in agriculture affects the economies of both the countries growing high-yielding varieties and their trading partners, it is important that all aspects of current semidwarf wheat cultivation be known and its potential be evaluated.

This report assesses the current situation with regard to the semidwarf wheat varieties developed in Mexico and the success of programs associated with their introduction and use outside of Mexico--in India, Pakistan, Turkey, and elsewhere. It also examines the relationships of wheat area, production, and yield.

In the compilation of this report, the author is indebted to numerous individuals in U.S. Agency for International Development (USAID) missions, U.S. Embassies, the International Maize and Wheat Improvement Center (CIMMYT), foreign Governments, private foundations, international agencies, and in Wash., D.C., who have volunteered their expertise in agronomy and the agricultural economics of the countries under study. The particular encouragement and assistance given the author of this work by James J. Naive deserves special note.

The choice of data and information for this report as well as the conclusions drawn are, of course, the sole responsibility of the author.

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The introduction and cultivation of newly developed high-yielding varieties of wheat (semidwarfs) in developing countries have been so successful in boosting wheat production as to be termed a Green Revolution.

In the period 1966-70, area given to the new varieties--chiefly by displacing local wheats--in India, Pakistan, Mexico, Turkey, Afghanistan, Tunisia, Iran, and Morocco expanded rapidly from 0.6 to 10.6 million hectares, while production rose spectacularly from 1.6 to 22.7 million tons. In 1970, semidwarf wheat in these countries accounted for 25 percent of the total wheat area and 49 percent of the total wheat output. In all countries, semidwarf yield per hectare greatly exceeded that of local varieties--often by two and three times. In 1970, high-yielding varieties averaged 2,140 kilos per hectare, compared with 770 kilos for local varieties. Average yields of all wheat have increased from 888 kilos per hectare in 1966 to 1,120 kilos in 1970.

Among the countries now using semidwarf wheat, results have been most dramatic in India where semidwarf production rose from 8,000 tons in 1966 to 13,606,000 tons in 1970, and in Pakistan where it increased from 14,000 to 4,350,000 tons in the same period. Because of adverse weather conditions, yields of these varieties in Turkey were less spectacular. But even here, semidwarf production rose from negligible amounts in 1966 to 1,797,000 tons in 1970.

On a worldwide basis, the 10.6 million hectares and 22.7 million tons of semidwarf production represent 5.2 and 7.9 percent of total wheat acreage and production, respectively.

Semidwarf wheats, developed in the early 1960's in Mexico by Nobel Peace Prize winner Dr. Norman E. Borlaug under the sponsorship of the Mexican Government and the Rockefeller Foundation, have the following characteristics: (1) Short and strong stems which reduce lodging and fallover; (2) greater response to fertilizer and water inputs; (3) photo-insensitivity which permits their cultivation in latitudes outside the normal growing belt; (4) earlier maturity which facilitates multiple cropping; and (5) good resistance to rusts and other diseases. A "package program" involving specific cultural practices has been developed to ensure successful cultivation of the high-yielding varieties.

HIGH-YIELDING VARIETIES OF WHEAT IN DEVELOPING COUNTRIES

by

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INTRODUCTION

The excellent performance of high-yielding semidwarf wheat in developing countries has been widely heralded as a major agrotechnological breakthrough. 1/ Because of the vigorous promotion of the wheat program and spontaneous response of the farmers, the high-yielding varieties (HYV) program has been termed a Green Revolution. Though the Green Revolution commonly refers to the introduction and successful use of high-yielding varieties of all grains, most of the acclaim has been given to the results of the semidwarf wheat varieties. 2/ This revolution in agriculture has contributed to a solution of the world food problem.

Although development of these varieties can be traced to the latter part of the 19th century, intensive research began only about 20 years ago. During this period many institutions, public and private, sponsored research on the wheat varieties and promoted their distribution to and use by farmers. These included the Rockefeller and Ford Foundations, the International Maize and Wheat Improvement Center (CIMMYT), the U.S. Department of Agriculture (USDA), the U.S. Agency for International Development (USAID), the Food and Agriculture Organization of the United Nations (FAO), and many universities and research institutions 3/ in both developing and developed countries. From the standpoint of international coordination of varietal improvement programs and the collection and distribution of seed stock (germ plasm), during 1968-69, CIMMYT distributed 146 shipments of germ plasm to 61 countries throughout the world (table 1).

The semidwarf wheat varieties that have been particularly successful in Mexico, India, and Pakistan were developed by Dr. Norman E. Borlaug and colleagues at the National College of Agriculture in Chapingo, Mexico, under

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1/ For further discussion of this development, see (4, 6, 7, 8, 13, 24). Underscored numbers in parenthesis refer to Literature Cited, p. 30.

2/ HYV rice varieties developed at the International Rice Research Institute at Los Banos, Philippines, have only had moderate success thus far (46), (95).

3/ See (24) for a fuller discussion of these institutions.

Table 1.--Shipments of research germ plasm by CIMMYT to six world regions, 1968-69

Germ plasm type	North America	South America	Near and Mid East	Europe	Africa	Others 1/	Countries receiving shipments
International spring wheat yield nursery	2	6	11	6	10	4	39
Commercial varieties	1	4	--	9	6	1	21
Advanced lines	2	3	3	2	--	1	11
F2	1	3	3	1	5	--	13
F3	1	3	1	3	2	3	13
International nursery for durum	1	2	6	3	3	2	17
International nursery for triticale	2	3	3	5	3	1	17
International screening nursery	1	4	3	1	4	2	15
Total shipments	11	28	30	30	33	14	146

1/ Includes USSR, Oceania, and the Far East

Source: (8), p. 81.

the joint sponsorship of the Mexican Government and the Rockefeller Foundation. 4/ These semidwarf wheats, which are generally less than 80 centimeters (32 inches) in height, are highly responsive to fertilizers when water supplies are adequate. They are generally classed as soft spring wheats. Because of their spring habit, the Mexican varieties cannot be raised in colder areas where conditions would require a period of dormancy. Having a short stiff straw, the semidwarf varieties 5/ show virtually no tendency to lodge or fall over. Photo-insensitivity is the characteristic which

4/ See (24, 40, 41) for a full discussion.

5/ Hereafter, the terms "semidwarf wheat", "HYV", and "Mexican wheat" will be used synonymously.

enabled Mexican wheat to be grown successfully outside of Mexico. Because of the insensitivity to length of daylight, they can be grown successfully within a wider latitudinal range throughout the world. Other high-yielding semidwarf varieties have been developed over the years in various countries, including the United States, but they have been unsuccessful when taken out of their natural habitat.

Experiments as well as experience show that for farmers to realize the potential of the HYV, the seeds must be used in conjunction with certain cultural practices. This recommended combination of seed use and cultural practices is called a "package program" 6/ The package program includes such cultural practices as adequate seedbed preparation; sufficient inputs of fertilizer, water (irrigation), and pesticides; and use of right type of implements. Without adequate application of inputs, for instance, HYV performance would not differ significantly from that of local varieties.

At the same time, governments have strengthened the agricultural infrastructure by improving farm extension service as well as marketing and distribution systems, and by implementing favorable farm price and subsidy policies.

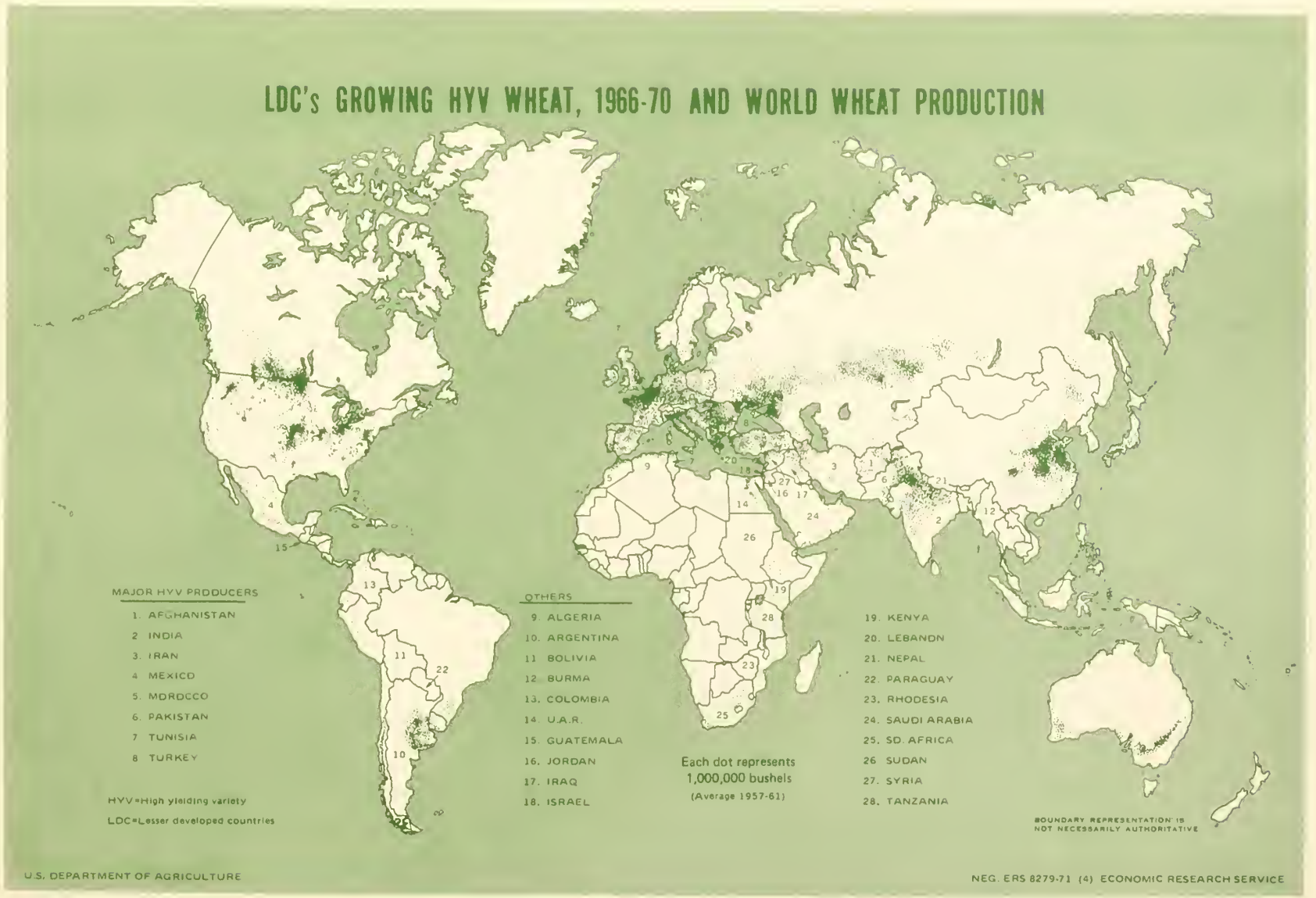
This report focuses on the extent to which the Mexican varieties and their derivatives have contributed to total wheat production in developing countries. Particular attention is given to the 1970 situation and--where information was available--the outlook for 1971. In addition, activities on the current status of semidwarf improvements or breeding projects are included. The intent of the report is to provide a better basis for evaluating the results of HYV programs.

Area coverage (see fig. 1) here includes all developing nations that have taken part in a semidwarf program, although emphasis is given to those that have been most active in sowing semidwarf varieties. 7/ Data on area and production of 1969 and 1970 are preliminary and subject to revision.

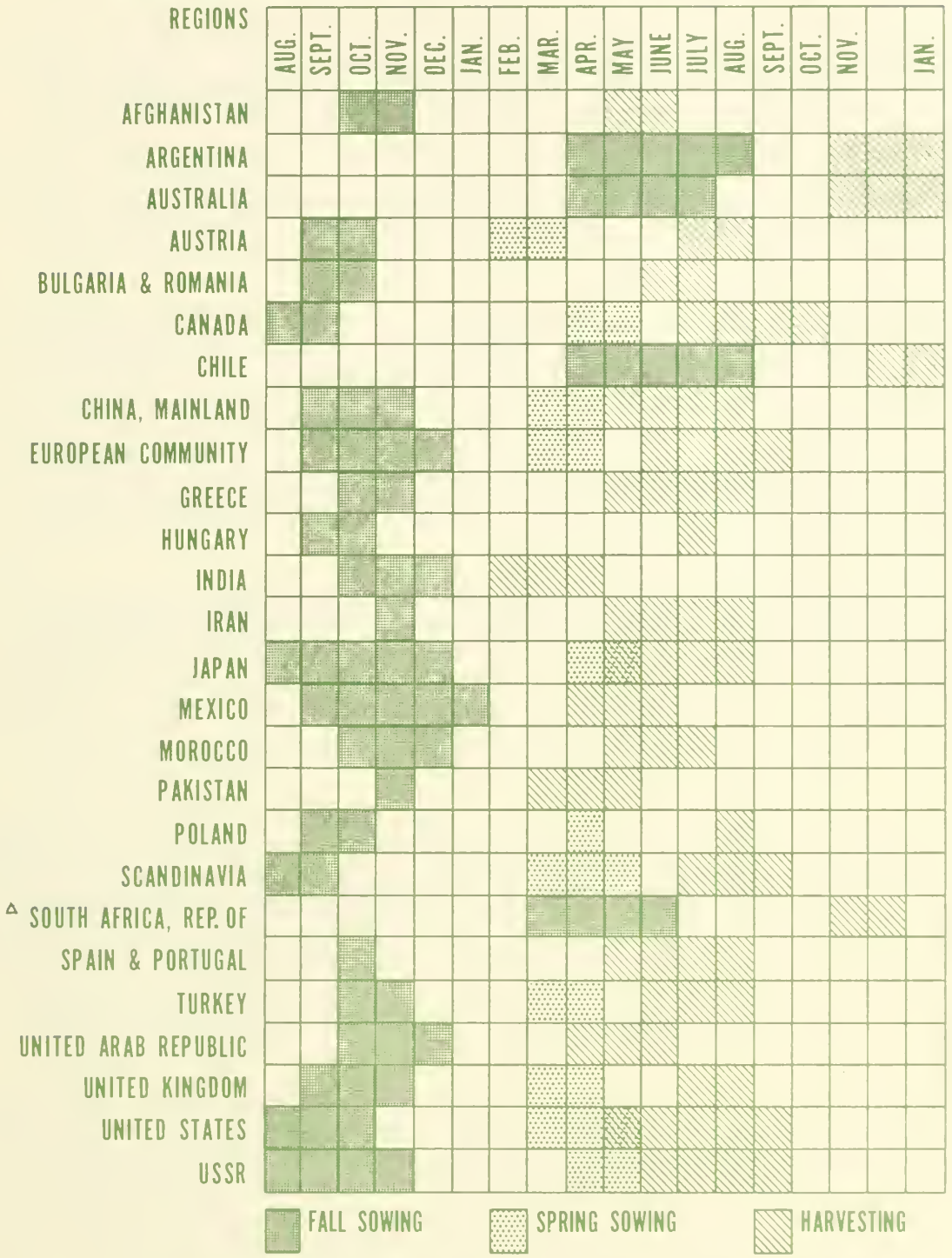
Sowing and harvesting seasons are shown in figure 2. For the most part, the wheat crop in the countries under review is sown in the fall and harvested in the spring of the following calendar year. Hereafter in this report, data on area, production, and yield will refer to the year in which the crop was harvested. Metric units are used unless noted otherwise.

6/ In India, a similar program for general agriculture was initiated in 1961 as the "Intensive Agricultural District Program (IADP)" by the Ford Foundation on the recommendation of a study group headed by Dr. Sherman Johnson.

7/ The discussions will center on eight countries--India, Pakistan, Mexico, Turkey, Afghanistan, Tunisia, Iran, and Morocco. In addition, other countries now in the testing and trial stage include Nepal, Burma, Syria, Jordan, Lebanon, Iraq, Israel, Algeria, Egypt, South Africa, Rhodesia, Kenya, Sudan, Saudi Arabia, Tanzania, Zambia, Argentina, Brazil, Bolivia, Colombia, Guatemala, and Paraguay.


LDC's GROWING HYV WHEAT, 1966-70 AND WORLD WHEAT PRODUCTION
MAJOR HYV PRODUCERS
1. AFGHANISTAN
2. INDIA
3. IRAN
4. MEXICO
5. MOROCCO
6. PAKISTAN
7. TUNISIA
8. TURKEY
HYV=High yielding variety
LDC=Lesser developed countries
OTHERS
9. ALGERIA
10. ARGENTINA
11. BOLIVIA
12. BURMA
13. COLOMBIA
14. U.A.R.
15. GUATEMALA
16. JORDAN
17. IRAQ
18. ISRAEL
19. KENYA
20. LEBANON
21. NEPAL
22. PARAGUAY
23. RHODESIA
24. SAUDI ARABIA
25. SO. AFRICA
26. SUDAN
27. SYRIA
28. TANZANIA
Each dot represents
1,000,000 bushels
(Average 1957-61)
BOUNDARY REPRESENTATION IS
NOT NECESSARILY AUTHORITATIVE
U.S. DEPARTMENT OF AGRICULTURE
NEG. ERS 8279-71 (4) ECONOMIC RESEARCH SERVICE

WHEAT SOWING AND HARVESTING SEASONS



THE SEASONS BEGIN WITH THE FALL SOWING IN THE NORTHERN HEMISPHERE; THE TIME SPAN IS 18 MONTHS. THE ABOVE SCHEDULE REPRESENTS THE MAJOR SOWING AND HARVESTING PERIODS ONLY. △ A SMALL AMOUNT OF SUMMER WHEAT IS ALSO GROWN BUT IS RELATIVELY UNIMPORTANT. SOURCES: 10, 12, 14, 15 AND SELECTED REPORTS FROM U.S. AGRICULTURAL ATTACHE

U.S. DEPARTMENT OF AGRICULTURE

NEG. ERS 1666-[illegible] ECONOMIC RESEARCH SERVICE

The expansion of semidwarf wheat area in the countries under study since 1966, when they were first grown outside of Mexico on a significant scale, has been spectacular. Area under cultivation increased from 0.6 million hectares in 1966 to 10.6 million hectares in 1970 (table 2). Most of the expansion occurred on irrigated land. The successful performance of these high-yielding varieties in 1966 and 1967 coupled with the dire need for accelerating food grain output in India and Pakistan spurred a tremendous area expansion in 1968 and 1969. The rate of expansion slowed somewhat in 1970 as available irrigated land decreased.

The area devoted to local varieties has declined over 8 percent since 1966, but the total wheat area has increased 21 percent. This indicates that the semidwarfs have not only replaced local wheats but also expanded into new areas. There is evidence that new land has been brought into cultivation with the expansion of irrigation and that semidwarfs have been substituted for other crops. Photo-insensitivity has permitted the HYV's to be grown in areas outside of the normal wheat belt. In addition, part of the gross area increase is due to more multicropping because the high-yielding varieties mature earlier than the indigenous varieties.

On a worldwide basis in 1970, the 10.6 million hectares and 22.7 million tons of semidwarf wheat in the countries under study were 5.2 and 7.9 percent of the total wheat area and production, respectively (32). These relationships are heavily influenced by the performance of Mexico, India, and Pakistan, which accounted for 80 percent of the 1970 total area and output of the eight countries. Turkey also has relatively large semidwarf areas (see appendix table 4).

All reports indicate that yields of these varieties markedly exceed those of the indigenous varieties. But yields fluctuate year after year primarily because of weather and input variations. The replacement of local varieties by semidwarf wheats appears to be the prevailing pattern. During the test plot and experimental stage, HYV yields are extremely high because sufficient inputs, proper cultivation, and better management are exercised in a limited area under appropriate control for growing. Initially, the semidwarf are sown on the most fertile lands, which are kept well irrigated and heavily fertilized.

However, yields tend to decline during the following stage. The main cause of this paradoxical situation is the rapid expansion of the HYV growing areas, particularly in countries where such sudden area increases take place under "crash programs." It is obvious that during this transitional period, insufficient supply and application of inputs plus the inexperience of farmers may adversely affect yields. Lands of lower fertility are gradually brought into the semidwarf wheat cultivation which would also limit the yield capacity. However, after this interim slippage period, the programmed activities are strengthened and HYV yields increase.

Table 2.--Wheat: Area and production of high-yielding and local varieties, selected countries, annual, 1966-70

Country and varieties		1966		1967		1968		1969		1970	
		Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
		1,000 ha.	1,000 tons	1,000 ha.	1,000 tons	1,000 ha.	1,000 tons	1,000 ha.	1,000 tons	1,000 ha.	1,000 tons
India	Local	12,653	10,416	12,324	10,115	12,056	8,697	11,165	7,460	10,515	6,487
	HYV	3	1/ 8	514.	2/1,278	2,942	2/7,843	4,793	3/11,191	6,111	3/ 13,606
	Total	12,656	10,424	12,838	11,393	14,998	16,540	15,958	18,651	4/16,626	4/20,093
Pakistan	Local	5,205	3,938	5,316	4,170	5,104	4,240	3,457	2,762	3,516	3,049
	HYV	5	14	101	224	957	2,237	2,388	3,949	2,833	5/4,350
	Total	5,210	3,952	5,417	4,394	6,061	6,477	6,045	6,711	6/ 6,349	6/7,399
Mexico	Local	--	--	--	--	--	--	--	--	--	--
	HYV	635	1,609	762	2,057	717	1,793	715	2,000	715	2,250
	Total	635	1,609	762	2,057	717	1,793	715	2,000	7/715	7/2,250
Turkey	Local	7,163	8,200	7,203.4	8,998	7,134	7,805	7,071	6,672	6,937	6,203
	HYV	n.a.	n.a.	0.6	2	170	8/595	579	8/1,628	623	8/1,797
	Total	7,163	8,200	7,204	9,000	7,304	8,400	9/7,650	9/8,300	9/7,560	9/8,000
Afghanistan	Local	2,280	2,033	2,364.2	2,547	2,350	2,594.2	2,745	2,490	2,819	2,291
	HYV	n.a.	n.a.	1.8	3	22	65.8	10/122	10/289	10/147	10/371
	Total	2,280	2,033	2,366	2,550	2,372	2,660	10/2,867	10/2,779	10/2,966	10/2,662
Tunisia	Local	845	349	815	282	649.2	381.5	627	326	697	330
	HYV	n.a.	n.a.	n.a.	n.a.	0.8	1.5	13	11/24	53	12/120
	Total	845	349	815	282	650	383	640	350	12/750	12/450
Iran	Local	4,000	3,190	4,400	4,000	4,800	4,400	4,590	3,884	4,610	3,680
	HYV	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10	13/16	90	13/120
	Total	4,000	3,190	4,400	4,000	4,800	4,400	14/4,600	14/3,900	14/4,700	14/3,800
Morocco	Local	1,637	814	1,777	1,090	1,977	2,410	1,759	1,606	1,869	1,850
	HYV	n.a.	n.a.	n.a.	n.a.	0.2	15/0.3	5	15/7	15/10	16/20
	Total	1,637	814	1,777	1,090	1,977.2	2,410.3	17/1,764	17/1,613	17/1,879	17/1,870
Total	Local	33,783	28,940	34,199.6	31,202	34,070.2	30,527.7	31,614	25,200	30,963	23,890
	HYV	643	1,631	1,379.4	3,564	4,809	12,535.6	8,625	19,104	10,582	22,634
	Total	34,426	30,571	35,579	34,766	38,879.2	43,063.3	40,239	44,304	41,545	46,524

Note: n.a. indicates not applicable or not available.

Sources: (over).

Sources: Data on total area and production 1966-70 (footnote 18, below); HYV area data (12) except where footnoted; high-yielding variety production data (6, 7, 8) except where footnoted:

1/ (6); Letter from James H. Boulware, Agricultural Attache, American Embassy, New Delhi, India, Jan. 1970.
2/ (35)
3/ USDA estimates (m.a.)*
4/ Agricultural Attache Office
1971. Agricultural Situation, American Embassy, New Delhi, India, Jan.
5/ _____
1970. Carl O. Winberg, Agricultural Attache, American Embassy, Rawalpindi, Pakistan, June.
6/ _____
1971. Grain and Feed Report, PK 1011, American Embassy, Islamabad, Pakistan, Feb.
7/ _____
1970. Annual Grain and Feed Report, MX0071, American Embassy, Mexico, Nov.
8/ _____
1970. Harvey R. Varney, Agricultural Attache, Embassy, Ankara, Turkey, June.
9/ _____
1970. Grain and Feed, TRO-076 American Embassy, Ankara, Turkey, Nov.
10/ _____
1970. RGA Request for PL 480 Wheat to AID, A-375, Joint American Embassy/USAID, Kabul, Afghanistan, Sept.
11/ (8) with USDA estimates (m.a.)*
12/ Agricultural Attache Office
1970. Agricultural Report, IN-0002, American Embassy, Rabat, Morocco, Dec.
13/ (8) with USDA estimates (m.a.)*
14/ Agricultural Attache Office
1971. Agricultural Situation, IR-1001, American Embassy, Tehran, Iran, Jan.
15/ (70, 71, 72)
16/ Letter from Ralph J. Edwards, AID Cereal Project Manager, Rabat, Morocco, July, 1970.
17/ Agricultural Attache Office
1971. Grain and Feed, MO 1006, American Embassy, Rabat, Morocco, Feb.
18/ Foreign Regional Analysis Division
1971. ERS Crop Data Base, U.S. Dept. Agr., Apr.

* methodology available.

The widespread acceptance of semidwarf varieties by growers during the period under review has been encouraging. Traditional cultural practices were apparently no obstacle to farmers' acceptance once the profitability of semidwarf production became evident. Government policies for both inputs and outputs have had an important role in providing economic incentives for cultivators. Information on these varieties was disseminated by word of mouth, the news media, and the existing extension system. In nearly all countries, plans for sowing semidwarf varieties were overfulfilled. In fact, demand was so strong that seed prices skyrocketed (8).

Before turning to individual country efforts and performance, it might be well to establish perspective by briefly discussing the history of semidwarf wheat production in Mexico, the originating country. The high-yielding semidwarf wheat varieties were released and quickly adopted by Mexico's growers in the early 1960's. They now account for over 90 percent of Mexico's total wheat area (46). Wheat yields increased from an average of 1,450 kilograms per hectare in 1957-59 to 2,670 kilograms in 1967-69. Current reports indicate that the national yield average is now 3,000 kilograms per hectare. As a result of higher levels of production, Mexico has become self-sufficient in wheat. Despite a considerable reduction in the area sown to HYV wheat, the Government has even had to cope with surplus wheat supplies (6, 7, 8, 14).

Mexican research work has been very active. CIMMYT and the National Institute of Agriculture Research (INIA) work very closely in all types and phases of researches at both local and international levels. (See section on CIMMYT, below).

TECHNOLOGICAL EFFECTS OF HIGH-YIELDING VARIETIES

The higher levels of 1968-70 wheat output in India and Pakistan associated with semidwarf technology are a sharp contrast to historical levels and trends. Figure 3 shows production in these years, compared with the linear trend for 1950-67. The fact that the 1968-70 observations fall far above the trend line is indicative that there has been a radical change in some aspect of wheat production from the previous pattern of development. Extrapolated 1950-67 trends would not reach the current levels of output in India and Pakistan until the end of the century.

Conceptually, semidwarf technology has caused the production function for wheat to shift upward. 8/ This is illustrated in figure 4 with supply curve S_1 representing the production function for the local wheat varieties and supply curve S_2 for the semidwarf varieties. At a given level of inputs per unit of land (I_1), there would be a yield of Q_1 units from S_1 and Q_2 units from S_2. The latter would exceed the former by Q_2-Q_1. The greater responsiveness of the semidwarf varieties to input changes is also illustrated in figure 4. If the level of inputs is increased from I_1 to I_2, the corresponding yield increases are Q_3-Q_1 for the local varieties (S_1) and Q_4-Q_2 for the semidwarfs. It is clear by visual inspection that Q_4-Q_2 is substantially greater than Q_3-Q_1.

8/ See (37) for a fuller discussion of this concept.


WHEAT PRODUCTION
THOUS. TONS
20
15
10
5
0
1950
'55
'60
'65
'70
1950-67 trend (Y = 6,435 + 316x)
INDIA
PAKISTAN
1950-64 trend (Y = 3,193 + 62x)

HYPOTHETICAL PRODUCTION FUNCTIONS FOR LOCAL AND HIGH-YEILDING VARIETIES OF WHEAT

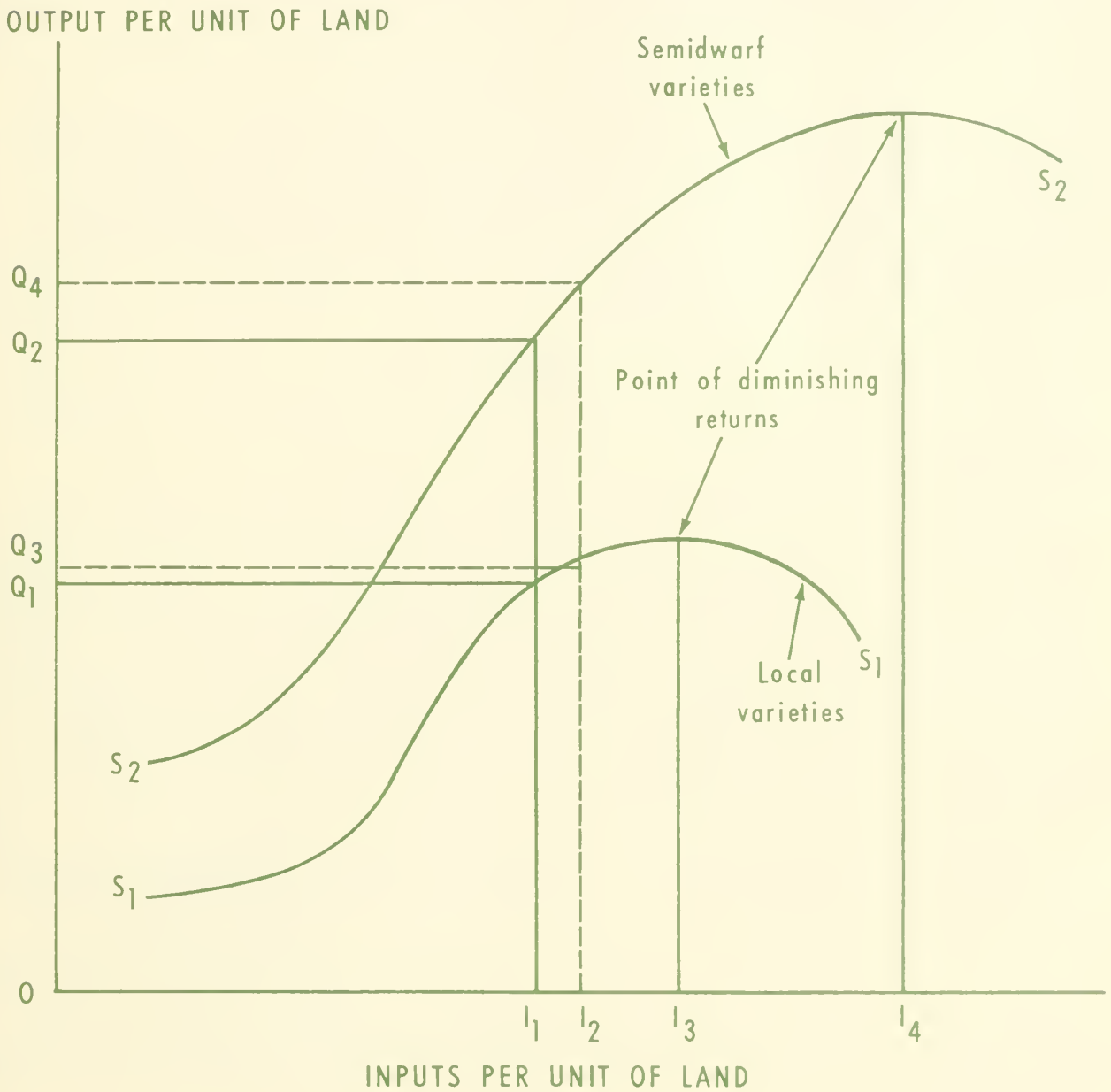


Figure 3 also demonstrates that at higher input levels, diminishing returns would set in for local and semidwarf varieties at input levels of I_3 and I_4. However, this occurs sooner for the local varieties (I_3). Again, this phenomenon reflects the greater input absorptive capacity of the semidwarf varieties.

The graphic evidence above supports the general recognition of a major technological breakthrough in wheat production. It is clear that future expectations should not be cast on the trends of the past, and that the stage has been set for a new growth pattern.

COUNTRY SITUATIONS

The following sections focus on the development, current situation, and trends of semidwarf wheats in the countries where they have been introduced. Where information is available, attention is given to factors limiting the expansion of semidwarf outputs as well as those contributing to expansion. These include land, climate, water availabilities, input supplies, agricultural institutions, and farm policies.

INDIA

Development

The first major shipment of 250 tons of semidwarf wheat from Mexico was imported by India in 1965. It was composed of the Mexican varieties, Lerma Rojo and Sonora 64, and was sown on about 3,000 hectares with excellent results. Thus, when the food situation in India became aggravated by the droughts in 1965 and 1966, the Government moved swiftly to import 18,000 tons of semidwarf wheat seeds from Mexico. This was the largest shipment of its kind in Indian agricultural history. The administrative speed and efficiency with which it was handled made the transaction even more remarkable. The seed was distributed in time for sowing the 1967 crop. Concurrently, the Government of India strengthened the package program 9/ for farmers by suggesting improved cultural techniques and providing necessary inputs (6).

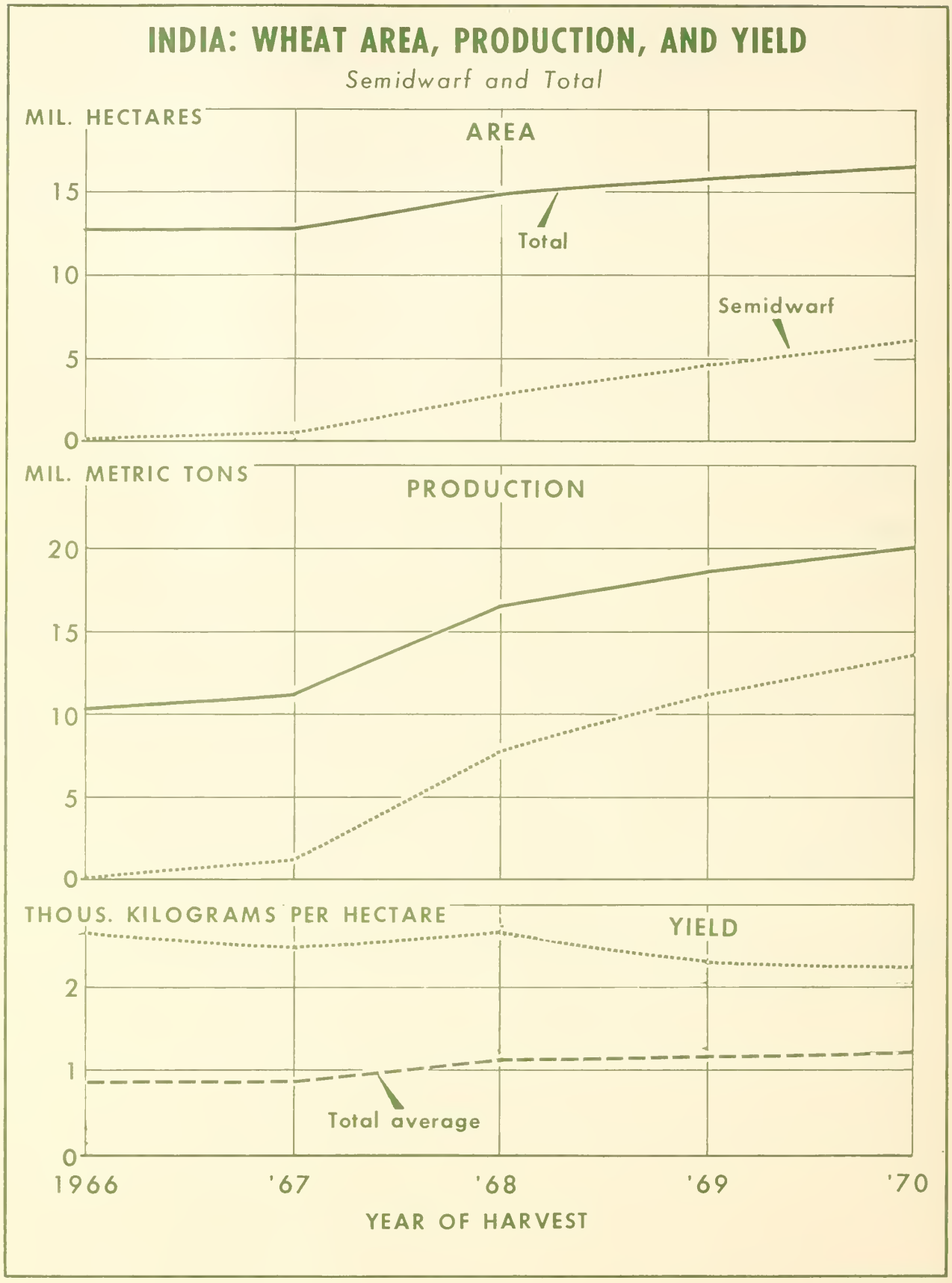
India's first major harvest of semidwarf wheat in 1967 was very successful despite relatively poor weather. An area of 0.5 million hectares, nearly all of which was irrigated, produced 1.3 million tons of semidwarf wheat; yields averaged 2,500 kilograms per hectare as opposed to only 820 kilograms per hectare for local varieties (table 3). This success constituted the first stage of India's shifting production function for wheat. Using seed from the 1967 crop and seed released from India's own breeding program, the semidwarf wheat area in 1968 was boosted to 3 million hectares, which accounted for 20 percent of the total. With very favorable growing conditions and increased application

9/ See footnote 6/.

Table 3.--India: Area, production, and yield of wheat; local and high-yielding varieties, annual, 1966-70

Items	Year harvested				
	1966	1967	1968	1969	1970
Area			1,000 hectares		
Local	12,653	12,324	12,056	11,165	10,515
Semidwarf	3	514	2,942	4,793	6,111
Total	12,656	12,838	14,998	15,958	16,626
Production			1,000 tons		
Local	10,416	10,115	8,698	7,460	6,487
Semidwarf	8	1,278	7,843	11,191	13,606
Total	10,424	11,393	16,540	18,651	20,093
Yield			Kg./ha.		
Local	823	821	721	668	617
Semidwarf	2,667	2,486	2,666	2,335	2,226
Average	824	887	1,103	1,169	1,209

Sources: Area and production same as table 2; yields computed from data in table 2.


INDIA: WHEAT AREA, PRODUCTION, AND YIELD
Semidwarf and Total
MIL. HECTARES
AREA
15
10
5
0
Total
Semidwarf
MIL. METRIC TONS
PRODUCTION
20
15
10
5
0
THOUS. KILOGRAMS PER HECTARE
YIELD
2
1
0
Total average
1966
'67
'68
'69
'70
YEAR OF HARVEST

of fertilizer, 1968 production of semidwarf wheat soared to 7.8 million tons and accounted for nearly one-half of the then record wheat harvest of 16.5 million tons. Average semidwarf yields, which increased to 2,700 kilograms per hectare, were particularly impressive in view of the greatly expanded grown area. The 1968 crop eliminated any lingering doubts about the potential of the semidwarf varieties and substantiated the view that a technological breakthrough had occurred and had been successfully implemented in the field (7). The semidwarf area in 1969 jumped to 4.8 million hectares, accounting for 30 percent of the total wheat area. Semidwarf yields dropped 12 percent however, because weather conditions were decidedly less favorable. But the yield levels were still relatively high and semidwarf output, which reached 11.2 million tons, accounted for 60 percent of the record crop of 18.7 million tons (8).

Situation and Outlook

India's third consecutive record wheat crop was harvested in 1970. Weather conditions were generally near normal though there was a delay of 5 to 8 weeks in the winter rains which affected the northern wheat-growing areas. The semidwarf area increased substantially to 6.1 million hectares. 10/ Yields still remained at a reasonably high level. Production increased 22 percent to 13.6 million tons, amounting to nearly 70 percent India's total wheat crop. Thus, in 1969 and 1970, the output of semidwarf wheat varieties exceeded that of indigenous varieties.

Initial weather conditions for the 1971 crop were very favorable. The June-September 1970 monsoon was the best since 1967. Soil moisture was sufficient for proper seeding, germination, and early growth. However, the October-December period was dry in the northern and central areas and may have retarded normal growth. But there have been no reports of unusual crop damage, owing in part to the large irrigated area for wheat. Winter rains commenced in late December and were expected to boost the 1971 crop (89). With increased application of inputs and expanded use of high-yielding varieties the outlook for India's 1971 wheat crop appears good.

Research Activities

The All-Indian Wheat Improvement Program was first concerned with the multiplication of imported semidwarf wheat to meet the expanding demand for seed. Since then, it has successfully conducted a program to cross local varieties with the imported Mexican semidwarf varieties. The imported varieties, while high yielding, were soft spring wheats with a relatively low protein content. In addition, the dark red color of the kernel was disapproved of by consumers who preferred the amber color of the local wheats for making chapattis 11/. There are 10 major research centers, 8 secondary centers, and many more research stations throughout the country in the program. The major ones are located at New Delhi, Ludhiana, and Pantnagar. Some of the resulting crosses retaining the high-yielding characteristic, have proven more suitable to consumers taste and preference. In 1967, several amber-colored highly rust-

10/ An unofficial early estimate was about 5.1 million hectares (12).
11/ Chapati--a pancake-like, unleavened bread, which is a basic food in India and West Pakistan (24).

resistant selections were released for commercial production under the names of S-227, Kalyansona (two-gene dwarf wheat), Sonalika, Safed Lerma, and S-331. An amber-seeded, high protein strain developed by treating Sonora 64 with gamma rays was also released under the name of Sharbati Sonora (7, 8).

On May 30, 1970, India released the first Triple Dwarf (3-gene) wheat variety--UP 301. (9). According to Dr. J. P. Srivastava of the Agricultural University of Uttar Pradesh, UP 301 possesses a high degree of resistance to most rusts and gives a fairly satisfactory yield. Moreover, its protein content is one-third higher than that of Kalyansona. Its 71-76 centimeter (28-30 inches) height, which is shorter than the original Mexican varieties makes it even more resistant to lodging. Its most attractive characteristic is a strong gluten content which is highly desirable for chapattis.

PAKISTAN 12/

Development

Semidwarf wheat varieites were introduced in Pakistan as early as 1960 by agricultural scientists who returned from a training program in Mexico with a small sample of seeds. Tests from this sample indicated that these high-yield varieties were adaptable to growing conditions in Pakistan. In mid-1964, Pakistan embarked on its Accelerated Wheat Improvement and Production Program, sponsored by the Government with the financial and technical assistances of CIMMYT and the Ford Foundation. The Government organized its economic and technical forces to achieve the designed objectives. In 1965, 350 tons of Penjamo 62 and Lerma Rojo 64 semidwarf seed were purchased from Mexico and sown on about 5,000 hectares (table 4). Yields averaged 2,800 kilograms per hectare--more than triple the average of local varieties. The severe drought in 1965-66 prompted officials to take bold actions to alleviate a mounting food crisis. In 1967, a purchase of 42,000 tons of semidwarf seed was made in Mexico and distributed to farmers in time for fall sowing. This represented the largest single purchase of imported wheat seeds ever negotiated. Nearly one million hectares or 16 percent of the total wheat area were seeded with these varieties and the resulting 1968 harvest was 2.2 million tons or one-third of the total wheat crop. Even though this was the first time that semidwarfs were grown on a large scale, yields averaged 2,300 kilograms per hectare.

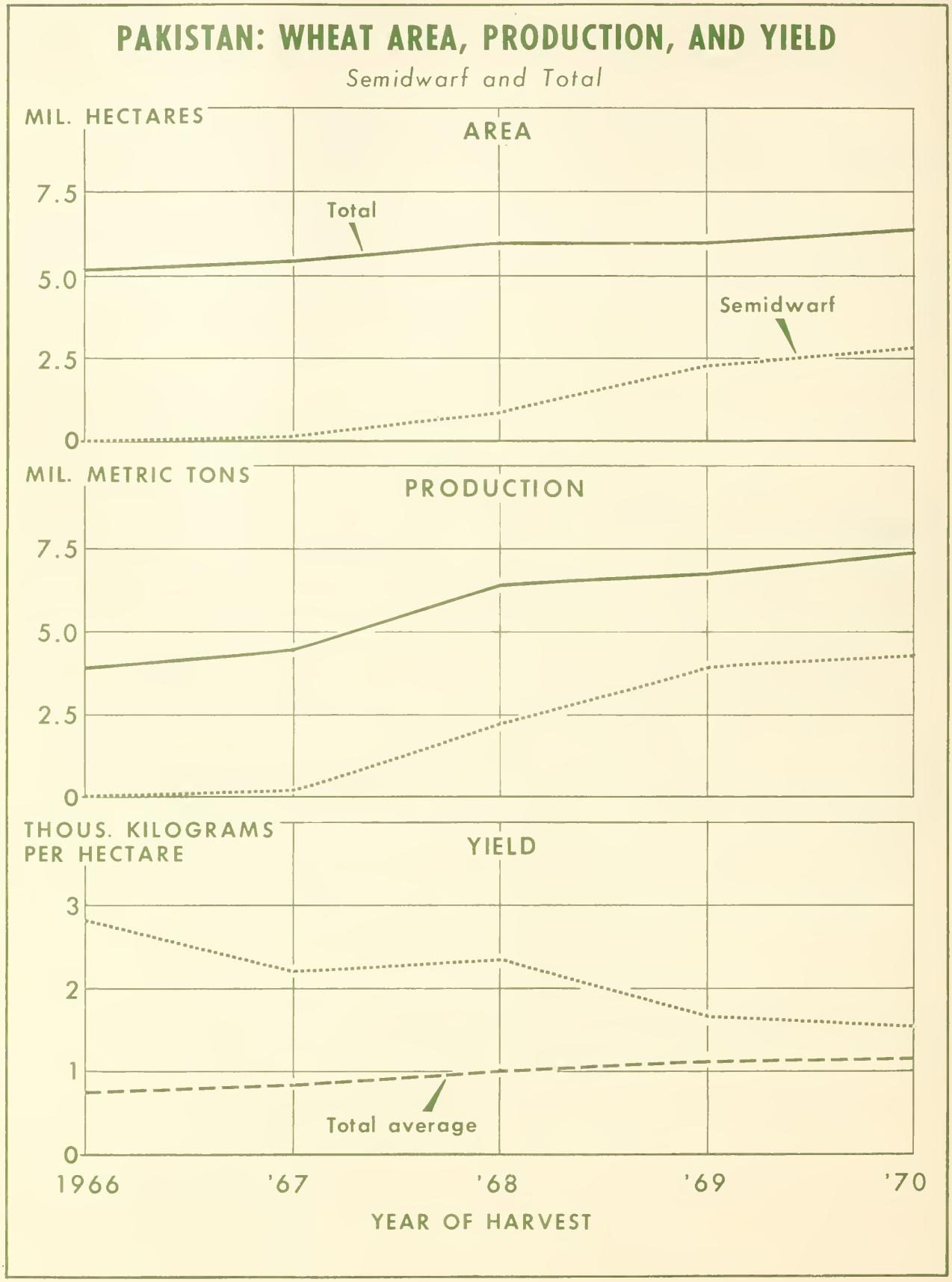
The 1968 crop was the basis for a large seed stock with which the semi-dwarf wheat area was expanded to 2.4 million hectares the following year. Semidwarf yields averaged 1,700 kilograms per hectare in 1969 and output accounted for three-fifths of total wheat production. The substantial decrease in yields was attributed to the expanded area (more than double) and less favorable weather. Yet HYV yields were still well above local varieties.

12/ The discussion in this section refers to West Pakistan, where nearly all of the wheat is raised.

Table 4.--Pakistan: Area, production, and yield of wheat; local and high-yielding varieties, annual, 1966-70

Items	Year harvested				
	1966	1967	1968	1969	1970
Area			1,000 hectares		
Local	5,205	5,316	5,104	3,657	3,516
Semidwarf	5	101	957	2,388	2,833
Total	5,210	5,417	6,061	6,045	6,349
Production			1,000 tons		
Local	3,938	4,170	4,240	2,762	3,049
Semidwarf	14	224	2,237	3,949	4,350
Total	3,952	4,394	6,477	6,711	7,399
Yield			Kg./ha.		
Local	757	784	831	755	867
Semidwarf	2,800	2,218	2,338	1,654	1,535
Average	759	811	1,069	1,110	1,165

Sources: Area and production same as table 2; yields computed from data in table 2.


PAKISTAN: WHEAT AREA, PRODUCTION, AND YIELD
Semidwarf and Total
MIL. HECTARES
AREA
7.5
5.0
2.5
0
Total
Semidwarf
MIL. METRIC TONS
PRODUCTION
7.5
5.0
2.5
0
THOUS. KILOGRAMS PER HECTARE
YIELD
3
2
1
0
Total average
1966
'67
'68
'69
'70
YEAR OF HARVEST

Situation and Outlook

On the whole, weather conditions in West Pakistan during the 1969-70 wheat growing season were satisfactory. However, in barani (rainfed) areas, drought occurred during November and December 1969 and the early part of 1970. Late January rains improved the situation markedly. If there was some adverse effect, semidwarf wheat would have suffered the least because of irrigation. Estimates relative to 1970 wheat output released by the Ministry of Agriculture and Works show an all time record of 7.4 million tons, an increase of 11 percent over the previous year. Total area also increased 5 percent over 1968-69, mostly for the high-yielding varieties. There was an estimated increase of 10 percent in semidwarf output accounting for close to 60 percent of total wheat production (table 2).

Lack of moisture during the 1970-71 sowing period resulted in a lower nonirrigated wheat area. Under normal conditions, there is usually adequate rainfall in November and December for germination and growth. However, if general drought conditions prevail, it might affect the total wheat output somewhat. It is estimated that the 1970-71 area could be at least the same or slightly above that of 1969-70. However, the area shifts from local to high-yielding varieties would be substantial, possibly up more than 20 percent over the previous year.

Research Activities

The Accelerated Wheat Improvement and Production Program, encouraged by the Government of Pakistan,has sponsored an intensive wheat research operation to increase the yields of semidwarf varieties and to improve semidwarf quality in terms of nutrition and consumer acceptance. The original varieties imported from Mexico have been crossed with indigenous varieties. Mexipak 65 is one such crossed progeny that is now being grown extensively in Pakistan. It not only has the high-yielding quality of the Mexican varieties but it is amber in color, thus increasing consumer acceptability for baking chapattis.

In addition, widespread microtrials in the past have established the superiority of three new varieties: Mangla 68, Norteno 67, and Iria 66. The first two are white grains and the third a red-type grain. They have been widespread in cultivation and have strengthened resistance to rust. Current activities concentrate on the yield performance, adaptability, and disease resistance of several promising lines. One such line in the evaluation stage is the triple-gene variety selected from the Mexican Cross II-23584.

The breeding program in Pakistan is broad and dynamic and is supported by CIMMYT with superior genetic materials. It also has extended its activities to agronomic and soils research recently.

Development

Turkey became one of the pioneers in raising semidwarf wheat when the Turkish Agricultural Research Station at Adapazari obtained 17 sample breeding stocks from Mexico in 1959 for testing. In 1965, 40 kilograms of semidwarf seed of Sonora 64 and Lerma Rojo were obtained by USAID from India. They were sown on a private farm in Tarsus and the resulting yields were surprisingly high. The excellent performance and exceedingly high yield of the semidwarfs aroused interest among neighboring farmers. As a result, a group of about 100 wheat cultivators in the Cukurova area pooled their financial resources and with Government assistance, procured 60 tons of Sonora 64 from Mexico. This lot was sown during the fall of 1966 in Adana region (23).

Weather was extremely favorable for grain production during the 1966-67 crop year and the 1967 wheat harvest totaled 9.0 million tons, a record high for Turkey (table 5). Naturally, the semidwarfs benefited from the favorable weather. Yields for the high-yielding varieties averaged 3,300 kilograms per hectare and on some experimental plots ran as high as 6,620 kilograms. In view of these encouraging facts, the Government decided to expand the semidwarf wheat area and established a wheat "crash program" for 1967-68.

At the direction of the Minister of Agriculture, Turkey purchased 22,000 tons 13/ of semidwarf wheat varieties, chiefly Penjamo 62, Lerma Rojo 64, Super X, and Mayo 64, from Mexico. Unfortunately, 1967-68 weather conditions were unfavorable. At the start, fall sowing was delayed by harvesting problems with cotton and sugar beets, which precede wheat in the multicropping system. Excessive rains slowed the cotton harvest. Earthquakes, which damaged sugar factories, also led to a delay in the beet harvest. As a result, only 17,000 tons of the available supply of semidwarf seed were sown, leaving a shortfall of 5,400 tons. The area sown to semidwarf varieties which totaled about 170,000 hectares, was centered in the lower plains in the Marmara, Aegean, and Mediterranean coastal regions. Following the sowing difficulties, there was a flood in the Adama region in January 1968, a cool spring, and then a dry spell in late May which adversely affected production.

Because of these unfavorable natural conditions, total wheat output for 1968 was down 600,000 tons from the previous year's record. Areas around the Anatolian Plateau suffered the most. 14/ Despite these adversities, the semidwarf varieties performed very well. They accounted for only 2.3 percent of the total area but yielded 7.1 percent of the total wheat crop. The HYV yields averaged 3,500 kilograms per hectare, a level indicative of success.

With the confidence of successful experience, cultivators and the Government, together with the assistance of international agencies, formed a "second

13/ 400 additional tons of semidwarfs were purchased from the United States (23).

14/ The Anatolian Plateau produces about 65-70 percent of Turkey's wheat.

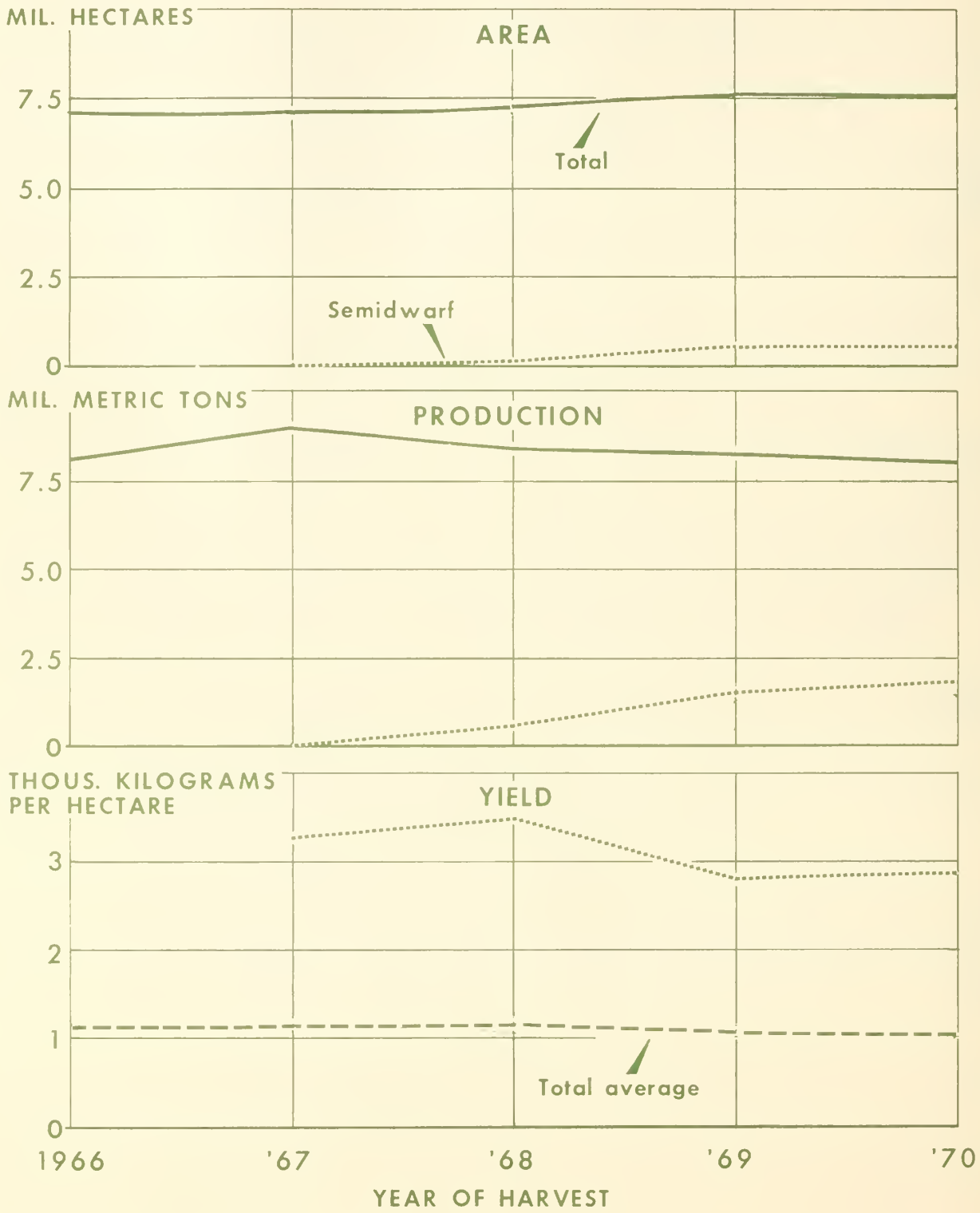
Table 5.--Turkey: Area, production, and yield of wheat; local and high-yielding varieties, annual, 1966-70

Items	Year harvested				
	1966	1967	1968	1969	1970
	1,000 hectares				
Area					
Local	7,163	7,203.4	7,134	7,071	6,937
Semidwarf	n.a.	0.6	170	579	623
Total	7,163	7,204	7,304	7,650	7,560
	1,000 tons				
Production					
Local	8,200	8,998	7,805	6,672	6,203
Semidwarf	n.a.	2.0	595	1,628	1,797
Total	8,200	9,000	8,400	8,300	8,000
	Kg./ha.				
Yield					
Local	1,145	1,249	1,094	944	894
Semidwarf	n.a.	3,279	3,500	2,812	2,884
Average	1,145	1,249	1,150	1,085	1,058

Sources: Area and production same as table 2; yield computated from data in table 2.

TURKEY: WHEAT AREA, PRODUCTION, AND YIELD

Semidwarf and Total



crash wheat program" for 1968-69. The multiplication of semidwarf seeds by Government farms plus the stock carried over by cultivators could not meet the huge demand. Some grain dealers were reported to have purchased early harvested semidwarf wheat at relatively low prices and shipped it to other areas for seed at a higher price. Of the 67 provinces, 24 were brought under semidwarf wheat cultivation. They covered the coastal areas where irrigation was readily available, and some interior plateau provinces. There was considerable substitution of semidwarf wheat for cotton, pastures, and other crops (23).

Weather conditions were very favorable during the late fall of 1968 and early spring of 1969. However, late spring rains and subnormal temperatures adversely affected the crop. There was also some winter kill on the Anatolian Plateau and floods in the Mersin area early in January.

The total 1969 wheat area was about 5 percent larger than the previous year; but production was down slightly. Under the second crash program, the semidwarf area expanded from 170,000 to 650,000 hectares. Semidwarf output surged from 600,000 to over 1.6 million tons. Though the yield of high-yielding varieties was down from previous year's high level, it was still substantially higher than that of local varieties. The unfavorable climatic conditions admittedly weakened yield potentials, but insufficient supplies of fertilizers and other inputs as well as less supervision of the cultivators under the crash program were responsible for the lower yield. Yet, had it not been for the semidwarf program, Turkey's 1969 total wheat harvest would have declined substantially.

Situation and Outlook

Total wheat output declined in 1970, marking the third consecutive disappointing crop. Adverse weather was again responsible. Late fall rains delayed sowing and retarded germination. Later, temperatures hovered around freezing in the central Anatolian and Thracean Plateaus, causing winter kill. The poor growing season was climaxed by the driest May and June on record. But most of HYV wheat grown in the coastal regions performed reasonably well. A harvest of 1.8 million tons accounted for 22 percent of the total output of 8.0 million tons. The most encouraging fact was that semidwarf yield was up 10 percent from 1969.

Although the gain of HYV wheat did not fully offset the reduction of the local varieties, it should be realized that if the area given to semidwarf wheat in 1970 had been sown with local varieties, total wheat production would have been at least 1.0 million tons lower. 15/

Thus far, weather conditions appear favorable for the 1970-71 wheat crop year, suggesting a departure from the previous 3 year years' unpleasant experiences. Timely fall rains encouraged cultivators to sow earlier, particularly

15/ This estimate is based on a yield of 1086 kilos per hectare (the 1961-65 average increased by 5 percent to take into account trend) and the semidwarf area of 650,000 hectares. This approach could be applied to the earlier years as well.

in the Anatolian Plateau areas. Germination had been fairly good, and wheat growing conditions are normal. The semidwarf wheat area is reported to have expanded substantially, compared with 1969 and 1970. If favorable climatic conditions continue and spring rains, particularly in May, are adequate, it is anticipated that the 1971 harvest will be better than that of recent years (90).

Research Activities

Since the early introduction of the HYV, the Government has launched a varietal improvement research program. In collaboration with the Rockefeller Foundation and CIMMYT, a Cooperative Center of Research and Training in Wheat Improvement was established in 1969 for Turkey and neighboring countries. A primary objective of the research program is to improve the semidwarf varieties with spring habits for the coastal regions and to develop high-yielding varieties with winter or semiwinter habits 16/ for the higher elevations of the Anatolian Plateau. A durum wheat-breeding program is also underway to develop frost-resistant varieties from Mexican wheat for higher-latitude areas. The research program of the Center also includes aspects of entomology and plant pathology (8).

AFGHANISTAN

With the help of USAID and CIMMYT, Afghanistan has developed a successful wheat program. With an initial shipment from Pakistan of 190 tons of seed, about 1,800 hectares were sown to semidwarf wheat in 1967 (table 2). The area was expanded to 22,000 hectares in 1968, and 122,000 in 1969. An estimated 150,000 hectares were sown to semidwarf wheat in 1970, accounting for 5 percent of the total wheat area. The HYV's yields have been good and these varieties now account for 14 percent of the total wheat output. However, the fact that much of Afghanistan's wheat is in high-elevation areas, which are cold and dry, is a constraint to HYV expansion (8). 17/

TUNISIA

Tunisia cultivates about 950,000 hectares of wheat, virtually all of which is rainfed crop. Average annual production during 1960-69 was about 410,000 tons and the yield was 430 kilos per hectare. Output only fills 50 percent of Tunisia's requirements. Approximately, two-thirds of the production is bread wheat, the remainder is durum.

With assistance from international institutions and agencies, Tunisia in 1967 launched The Project for Increased Cereal Production (ACPP). Five

16/ These are derivatives from crosses between spring and winter varieties developed by Dr. J.A. Rupert at Davis, California.

17/ The reader is reminded that the semidwarf varieties developed in Mexico are spring wheats which do not have the dormancy characteristic needed to withstand cold weather.

agronomists from CIMMYT were assigned to help implement this program. Three Mexican dwarf varieties (Inia 66, Tobati 66, Sonora 63) were sown on 800 hectares. The 1967-68 crop was very successful; 1,500 tons of HYV wheat were harvested and yields far exceeded local varieties. In 1969, the HYV area expanded to 13,000 hectares. With favorable weather, the national wheat program was spectacularly impressive during the 1968-69 season. The HYV production was about 24,000 tons and yields reached as high as 3,000-4,000 kilograms per hectare. The achievements encouraged the Government to boost the HYV area to 53,000 hectares for the 1969-70 crop. With more experienced cultural practices and normal weather conditions, HYV output in 1970 increased fivefold over 1969 to 120,000 tons. However, local varieties in the south and central areas were adversely affected by weather and outbreaks of rust-damaged durum.

A goal of 100,000 hectares was set for the 1971 HYV area. With favorable weather, this area could produce as much as 150,000 tons of HYV wheat. However, rains during late 1970 delayed sowing, possibly causing below average yields.

The varietal improvement section of the Wheat Project in ACPP was established in cooperation with INRAT (National Institute of Agricultural Research of Tunisia) and the assistance of CIMMYT and USAID. It covers a very broad research area. The excellent start during 1968-69 and the enthusiasm already generated by the success of the production program, may well evolve into a base for general improvement throughout North Africa (6, 7, 8).

IRAN

Iran has a wheat area of nearly 4 million hectares (1960-69 average). The long-time national average yields are low, about 840 kilograms per hectare; with 600 kilograms per hectare on rainfed land and 1,200 kilograms per hectare on irrigated land. To improve yields, Iran started wheat breeding over 30 years ago. Technical assistance has been obtained from international agencies and institutions. Varietal improvement is pursued throughout the wheat area; however, the major wheat problem is rust disease.

In 1969, Iran first sowed the high-yielding varieties of wheat on 10,000 hectares. The seed stock (Penjamo 62, Inia 66) originated from Mexico, but was imported from Turkey. The HYV harvest was 16,000 tons in 1969 and the yields substantially exceeded the native varieties. Although rusts occurred and some crops were damaged, grains of HYV (particularly Inia 66) filled out well in all locations. Encouraged by this, Iran expanded its HYV area to 90,000 hectares in the 1969-70 crop season by using 1,500 tons of seed stock (Penjamo 62) imported from Denmark as well as seed retained from previous semidwarf crops. The substantial increase of semidwarf area boosted 1970 output to 120,000 tons, although total wheat harvest decreased from 3.9 million tons in 1969 to 3.8 in 1970. This decrease was due to the shortage of rainfall.

The Government plans to increase the wheat area for 1970-71 by 70,000 hectares. However, because of prolonged dryness in the wheat area in 1969-70, the size of the 1970-71 crop remains to be seen.

Iran's northern plains are considered promising for ground water development. Many local varieties have already been replaced in much of the area. Government policy to encourage wheat production encounters increased competition from other crops for the same fertile soils. However, there is still a good deal of uncultivated area in mountain regions where rain is adequate. These areas should eventually be exploited for the high-yielding varieties and new technology.

The present HYV collection and distribution program could be made more efficient and the results improved. Agronomic research should be conducted immediately to determine what modifications in cultural practices are needed to further adapt the dwarfs to Iranian conditions (8).

MOROCCO

Morocco began its semidwarf wheat production in 1968 with an area of 200 hectares of Siete Cerros, Inia 66, Penjamo 62, and Tobari 66. Owing to the good yields realized, 500 tons of five semidwarf varieties were imported the next year from Mexico and planted on an area of 5,000 hectares. Unfortunately, excessive rainfall caused a very serious epidemic of septoria leaf and glume blotch on both semidwarf and local varieties. Still, the HYV greatly outperformed indigenous varieties.

The HYV area expanded considerably in 1970 to 10,000 hectares. The 1970 semidwarf wheat harvest is estimated to be 20,000 tons against only 7,000 tons in 1969; the increase is attributed to expanded area, favorable weather, and fewer disease problems.

The 1971 outlook appeared favorable after rains in late December 1970 broke a dry spell. However, output still depends upon weather conditions during the remainder of the crop year (table 2).

Although Morocco possesses extensive lands suitable for wheat, erratic and unseasonable rainfall is a negative factor in expanding the semidwarf wheat area. The HYV's have performed well under adequate rainfall conditions (70, 71, 72).

A cooperative project with CIMMYT to find disease-resistant varieties is now in progress. More than 2,000 lines and varieties of experimental wheats, mostly of Mexican origin, were grown.

OTHER COUNTRIES

Other countries, though not yet adopting semidwarf wheat on a significant scale, have been preparing for future introduction. Countries in this group are engaged in plot testing and varietal improvement for disease resistance, higher yields, and better quality.

Wheat production in Nepal accounts for only 3 percent of the total food grain output (rice 68 percent, corn 25 percent, and millet 4 percent). Since Nepal is very mountainous, the growing area is centered in Katmandu Valley and Terai, an extension of the Gangetic Plain. In recent years, with the assistance of USAID, the Ford Foundation, India (Indian Aid Program), and other agencies, Nepal has been active in growing high-yielding cereal varieteis, particularly semidwarf wheat. In 1965, Nepal imported 38 tons of Mexican wheats (mainly Lerma Rojo) from India, from which a good harvest was realized. In the following year, 450 more tons of the same variety were shipped from India. Reports indicate that despite the unfavorable weather (mostly droughts) since 1964, Nepal has continued the wheat expansion program. Area and production data pertaining to HYV and total wheat are very sketchy. However, some sources estimated that the HYV area has increased from 1,400 hectares in 1966 to 75,000 in 1970. It may be assumed that Nepal's HYV wheat program has contributed to its food supply. This assumption is evidenced by the continuous area expansion and extensive assistance rendered by outside agencies.

In cooperation with CIMMYT, Argentina has been concentrating on research and breeding since 1968. Ninety advanced generation lines of the semidwarf wheat were included in the yield tests. Argentina's breeding research includes durum wheat (8).

With the support of the Ford Foundation, Lebanon has been conducting the "Arid Lands Agricultural Program." A cooperative wheat improvement program for a number of Near and Middle East countries, including Jordan, Iraq, and Iran, has also been developed. The program is closely related to CIMMYT and Ford Foundation activities. This spring wheat breeding program is also being delivered for the coastal areas of Turkey (18, 19). An intensive research program for semidwarf varieties in North Africa is centered in Tunisia. All these research works are carried out by the Project for Increased Cereal Production (ACPP) and the National Institute of Agricultural Research of Tunisia (INRAT) with the cooperation of CIMMYT, USAID, and other agencies. Attacks of powdery mildew were heavy throughout the regions, permitting selection for resistant lines. All known insects of North Africa are being used in tests to improve resistance (8).

Colombia initiated a sound and successful wheat program relatively early. The Rockefeller Foundation has provided extensive technical assistance. Later the Colombian Agricultural Institute (ICA) was established and has since developed more than a dozen improved wheat varieties. The impact of this program has practically reached all farmers. However, wheat is a minor crop in Colombia (about 3 percent of total crop area); cultivators and the Government tend to shift their interest from wheat to other more profitable crops. Barley, for example, the major crop for the beer industry, is in great demand. Consequently, the wheat program so far has been flagging. Only 8 percent of Brazil's food crop is wheat; its major food staples are rice and corn. With

the assistance of FAO, Ford Foundation, CIMMYT, and USAID, wheat production increased from a low of 120,000 tons in 1963 to 360,000 in 1967, 600,000 in 1968 and 1,730,000 in 1970. Improved seeds have been used widely on the growing area centers on Rio Grande do Sul in the South. The relatively high price of wheat against rice has stimulated a significant shift in production from rice and other crops to wheat. The National Wheat Program of Paraguay began in 1965, and the improved seeds have been used since then. USAID has been providing technical assistance rather actively in this country.

CIMMYT

Research on new wheat varieties has been intensified since the breakthrough of the semidwarfs. Under the leadership of CIMMYT, coordination among many countries throughout the world has been expanded and strengthened. Major research projects include the blending of germ plasm complexes of spring wheat and hard winter wheat, in the hope of developing new winter, semiwinter, and spring varieties with higher yields. Hybrid wheat seed is also under intensive research. CIMMYT has developed restorer lines capable of restoring fertility to certain cytoplasmic sterile male types of wheat. Another project involves crossing Mexican semidwarf wheat with rye to develop triticales which may even outyield the HYV's. The improvement of wheat quality--higher protein and essential amino acid content--has gained substantial ground. Research work on durum has developed an excellent program. Many are light insensitive, have fair fertility, and are disease resistant. Durum is also used as a parent in the triticale-breeding program. CIMMYT also has broadened the spectrum and increased the depth of the genes for resistance to rusts and other diseases. Research on three-gene wheat varieties has gained remarkable momentum. Some countries have even distributed some triple gene seeds for trial commerical production. Numerous experimental materials have been distributed on a worldwide basis by CIMMYT for further research purposes. 18/

CONCLUSIONS

Based on past developments and recent situations of the semidwarf wheat program in the developing countries, it appears likely that the momentum generated in the programs discussed above will continue. It is expected that under normal climatic conditions wheat output will continue to increase. The pace of development may vary because each of the countries is at a different stage of program implementation.

However, the pace of development will largely depend on:

(1) The direction of governmental policies and efforts. If food were in

18/ See table 1.

relatively adequate supply, attention and priorities might be directed to other problem areas to achieve a national objective of total economic growth and development. However, regardless of circumstances, the program itself or at least phases of the program should now be self-perpetuating;

(2) The efficiency of the institutions and infrastructure within the framework of the regulated program. Future programs should be directed towards strengthening and coordinating activities for future expansion. Minor changes may occur from time to time to comply with the changing agricultural policies;

(3) The dissemination of knowledge to farmers. The package concept should be made known to cultivators. Apart from cultural methods and other requirements, the application of inputs to optimize output should be considered the key point for the whole operation. There is evidence in countries producing semidwarfs that cultivators' use of fertilizer is well below optimal levels for maximizing returns;

(4) The investment and performance of the private sector. Efforts and capital from the private sector should continue to flow into the programs; there is ample room for profits to encourage continuous investment. Greater involvement of the private segment would necessarily provide more permanency to the program. Hence, with a firm foundation, constant progress could be maintained without further major efforts by the Government;

(5) The area given over to semidwarf wheats. The area for raising HYV wheats could be expanded in areas currently used as well as in other parts of the world. However, at present, the greater portion would come from replacing those traditionally low-yield wheat-producing areas, where the irrigation system and water supplies can be improved. In some favorable ecological areas, much of the marginal lands can also be utilized profitably. The most hopeful approach for expansion is through intensive breeding and research. New varietal wheats possessing the capability of growing in areas beyond the traditional wheat belt would be the force for further expansion. Encouragement of multiple cropping would also benefit the semidwarf wheat program;

(6) The effectiveness of research on new improved varieties. Current research and the expanded research areas should provide the base for continuous varietal improvements. Public concern as to how soon and to what extent the next technological breakthrough will take place is unknown and unpredictable. The efforts, investment, and performance of the countries already involved in this program could serve as guidelines for evaluating the whole future program.

There may not be another surge in output such as that caused by the rapid and successful introduction of the semidwarf wheat in India and Pakistan. The success there occurred under very propitious conditions and situations. But with the wheat research activities now underway, technical improvements should continue to flow into the production programs at a relatively good rate. Therefore, we should be able to look forward to a continuing betterment of quality and yields in the countries under study in this report.

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APPENDIX

Appendix Table 1.--India: Area, production, and yield of wheat, annual 1966-1970 and averages 1961-65 and 1968-70

Year of harvest	Area	Index	Production	Index	Yield	Index
	1,000 ha.		1,000 tons		Kg./ha.	
1961-65	13,402	100	11,202	100	836	100
1966	12,656	94	10,424	93	824	98
1967	12,838	96	11,393	102	887	106
1968	14,998	112	16,540	148	1,103	132
1969	15,958	119	18,651	167	1,169	140
1970	16,626	124	20,093	179	1,209	150
1968-70	15,861	118	18,428	165	1,162	139

Source: Table 2, reference (18).

Appendix Table 2.--Pakistan: Area, production, and yield of wheat, annual 1966-70 and averages 1961-65 and 1968-70

Year of harvest	Area	Index	Production	Index	Yield	Index
	1,000 ha.		1,000 tons		Kg./ha.	
1961-65	5,065	100	4,203	100	830	100
1966	5,210	103	3,952	94	759	91
1967	5,417	107	4,394	105	811	98
1968	6,061	120	6,477	154	1,069	129
1969	6,045	119	6,711	160	1,110	134
1970	6,349	125	7,399	176	1,165	140
1968-70	6,152	121	6,862	163	1,115	134

Source: Table 2, reference (18).

Appendix Table 3.--Turkey: Area, production, and yield of wheat, annual 1966-1970 and averages 1961-65 and 1968-70

Year of harvest	Area	Index	Production	Index	Yield	Index
	1,000 ha.		1,000 tons		Kg./ha.	
1961-65	6,807	100	7,050	100	1,036	100
1966	7,163	105	8,200	116	1,145	105
1967	7,204	106	9,000	128	1,249	121
1968	7,304	107	8,400	119	1,150	111
1969	7,650	112	8,300	118	1,085	105
1970	7,560	111	8,000	113	1,058	102
1968-70	7,505	110	8,233	117	1,100	106

Source: Table 2, reference (18).

Appendix Table 4.--Area and production of local and HYV wheat varieties as a percentage * of total wheat for selected countries, annual, 1966-70

	1966		1967		1968		1969		1970	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
	Percent									
India										
Local	100	100	96	89	80	53	70	40	63	32
HYV	n.a.	n.a.	4	11	20	47	30	60	37	68
Pakistan										
Local	100	100	98	95	84	65	61	41	55	41
HYV	n.a.	n.a.	2	5	16	35	39	59	45	59
Mexico										
Local	---	---	---	---	---	---	---	---	---	---
HYV	100	100	100	100	100	100	100	100	100	100
Turkey										
Local	100	100	100	100	98	93	92	80	92	78
HYV	n.a.	n.a.	n.a.	n.a.	2	7	8	20	8	22
Afghanistan										
Local	100	100	100	100	99	98	96	89	95	86
HYV	n.a.	n.a.	n.a.	n.a.	1	2	4	11	5	14
Tunisia										
Local	100	100	100	100	100	100	98	93	93	73
HYV	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	7	7	27
Iran										
Local	100	100	100	100	100	100	100	99	98	97
HYV	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	2	3
Morocco										
Local	100	100	100	100	100	100	100	100	98	96
HYV	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	4
Total										
Local	98	95	96	90	88	71	79	57	75	52
HYV	2	5	4	10	12	29	21	43	25	48

* Some percentages indicate 100 resulting from rounding. Note: n.a. indicates not applicable or not available.

Source: Table 2.

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